

ON SOME ASPECTS OF QUANTUM BIOPHYSICS

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Abstract. In the paper the free radical oxidation process in physiology is considered from the mathematical point of view. The process is described by the nonlinear Semionov equation with the appropriate initial conditions. The solutions are obtained in the explicit form. Numerical examples are given.

Keywords and phrases: Free radicals, Semionov equation.

AMS subject classification: 85A30, 35Q40.

The main purpose of quantum biophysics is a study of quantum phenomena connected with biological systems. Erwin Schrödinger was one of the first scientists who suggested a study of quantum biology [4]. In the paper we will consider a free radical oxidation in a living organism. Free radical oxidation may take place in any system (including human and animal organisms) in the presence of both a background ionizing radiation and an oxygen biradical in unsaturated fatty acids or aldehydes. The activation of free radical oxidation in the tissues of humans and animals under the impact of ionizing radiation was discovered by Boris Tarusov in 1954 [1,2,3,5].

A free radical is a particle with an unpaired electron on the valence shell but having no electrical charge. Electron is a particle with a negative elementary electric charge of -1.610_{-19} coulomb. Additionally the electron has an intrinsic angular moment or the so called spin of $1/2$. In relation with this the electron has an intrinsic magnetic moment along its spin axis. In the absence of an external magnetic field all spins in a system are oriented chaotically. Usually in molecules any two electrons residing in the same orbital have oppositely oriented spins and their magnetic moments compensate each other, so that the molecules are chemically less active. In order to get molecules activated, the valence shell electrons have to be transferred to higher orbitals, either singlet (S_0 , S_1 or S_0 , S_2) or triplet (S_0 , T_1). This can be achieved by absorption of light quanta (Fig. 1).

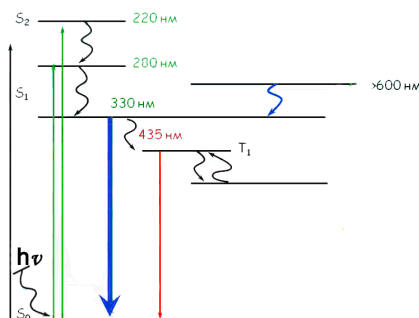


Fig. 1. The illustration of the absorption of light quanta

Ionizing radiation may cause removal of one of the electrons in the molecule thus producing ions. Ions R^+ , R^- or dipoles $R^{\Delta+}$, $--R^{\Delta-}$ are particles with uncompensated charge and the resulting electric field is the physical basis of their chemical activity. If an object carrying free moving or unpaired electrons is placed in a constant magnetic field (intensity H), most of the electrons will become oriented along that field with minimal energy $S = -1/2$, however, a minor part of electrons, those with higher energy $S = +1/2$, will get oriented in the opposite direction (Zeeman splitting) [1,2,3,5].

Lande g -factor shows the share of spin and orbital magnetisms in the overall magnetism of an unpaired electron. Bohr atomic magneton β is an elementary unit of magnetism determining the magnetic moment of the nucleus, and it is much lower than the magnetic moment of the electron. Orientation of spins in the magnetic field leads to the orientation of the radicals on the whole, that is causing their polarization with the subsequent changes of the valence angles resulting in changes of the reaction abilities of the radicals.

In 1944 Yevgeny Zavoisky [1,2,3,5] has discovered that equivalence could be reached between the ultra high frequency electromagnetic radiation acting on a system containing free radicals and the difference in the energy of Zeeman levels of that system

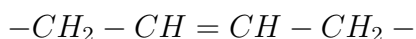
$$h\nu = \Delta E = +1/2g\beta H - (-1/2g\beta H) = g\beta H.$$

Zavoisky managed to achieve equal distribution of spins of paramagnetic particles in the case of Zeeman splitting through irradiation of the system with the light of ultra high frequency. It turned out that application of such an approach could help in calculation of the number of the paramagnetic atoms in the system and in determining of their nature.

In 1954 Boris Tarusov [1,2,3,5] made two fundamental observations:

1. In biology - Activation of non-enzymatic free radical oxidation of unsaturated fatty acids in human and animal tissues caused by such a powerful factor as the ionizing radiation;
2. In medicine - Development of free radical pathology in the presence of an excess of the products of free radical oxidation of the unsaturated lipids: free radicals, aldehydes and ketones of the peroxides of the unsaturated fatty acids in case of acute radiation syndrome.

In 1960 Alexandre Zhuravlev and Elena Burlakova [1,2,3,5] have shown that non-enzymatic free radical oxidation in the human and animal tissues could be always observed though at a very low level. High chemical activity of unsaturated fatty acids can be attributed to the double bonds they have: oleic acid - 1, linoleic acid - 2, linolenic acid - 3, arachidonic acid - 4.



Membrane phospholipids usually have one saturated and one unsaturated fatty acid. However, some possible excess of polyunsaturated fatty acids in phospholipids is somewhat diluted by the presence of less reactive saturated fatty acids (palmitic and stearic). Also membranes contain cholesterol which serves for limiting and braking the oxidation of unsaturated fatty acids.

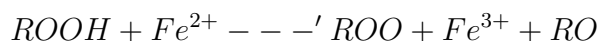
1. Initiation - Background ionizing radiation both of cosmic and global origin is the continuously acting factor. If the energy of radiation exceeds 4 eV, free radicals can be formed both in water and hydrophobic parts of membranes.

2. Chain propagation - The primary short-living radicals of the unsaturated fatty acids R and $R - R$ quickly react with the oxygen producing peroxide radicals ROO



Peroxide radicals attack the moving atoms of hydrogen producing hydroperoxides and new R s, which again react with the oxygen endlessly continuing the chain reaction. The number of active radicals forming in the course of the chain reaction is far higher than in the beginning and the rate of the process of free radical oxidation is quite high.

3. Chain branching - in case the peroxides split in two radicals, the chain reaction may branch off



Each newly formed radical starts a new chain and the reaction continues self-accelerating with no external energy factor intervening. Therefore regulation of the rate of the free radical oxidation only can be achieved by braking it.

But of course, there exist substances, that inhibit chain reactions mediated by free radicals, such as ascorbic acid, lemon acid, salicylic acid, cysteine, glutamine, tocopherol, superoxide dismutase. These substances are found in human tissues as well. Also some lipids in liver, heart and brain inhibit chain reactions.

Under the influence of the inhibitors concentration of activation centers within free radical reaction is given by the Semionov equation

$$\frac{\partial n}{\partial t} = \omega_0 + f(n, t) - g(n, t) \quad (1)$$

with the initial condition $n|_0 = n_0$, where n is the concentration of radicals, ω_0 is the initial velocity of formation of free radicals, $f(n, x, y, z)$ is the velocity of formation of activation centers and is the given function, $g(n, t)$ is a velocity of death of active centers.

By analysing formula (1) we obtain, that the condition

$$\omega_0 + f(n, t) - g(n, t) = 0$$

means that the formation of free radicals is stopped. So if we can manipulate with the functions $f(n, t)$, $g(n, t)$, the reaction will be inhibited.

Here we consider the simple case: n is the function only of time t , $f(n, t)$, $g(n, t)$ depend only on n and time t .

Suppose, $f(n, t) = ke^{ant}$, $g(n, t) = g_0n$, where k, a, g_0 are the given constants. Then from (1) we obtain

$$t = \int_0^n \frac{dy}{\omega_0 + ke^{ayt} - g_0y} + n_0, \quad 0 < t < t_0. \quad (2)$$

Below in Fig. 2 and Fig. 3 the graph of function (2) is constructed by using Maple-12 and the following data $\omega_0 = 1; k = 1; a = 1; g_0 = 1; n_0 = 5$ and $\omega_0 = 1; k = 1; a = 1; g_0 = 1; n_0 = 5$.

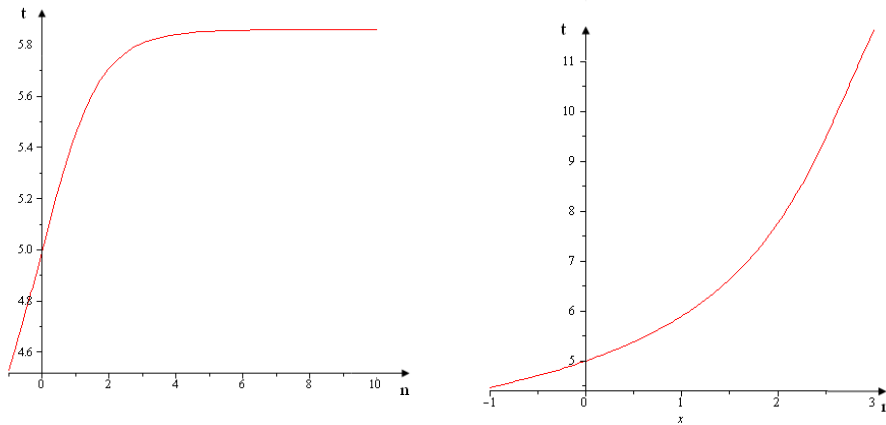


Fig. 2,3. The distribution of the activation centers for the different data

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